

**DISK DRIVE EMPLOYING A SPINDLE MOTOR COMPRISING A LOCKING
SPRING ARM DISENGAGED THROUGH STATOR COIL FLUX**

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to disk drives. More particularly, the present invention relates to a disk drive employing a spindle motor comprising a locking spring arm disengaged through stator coil flux.

Description of the Prior Art

The spindle motor within a disk drive typically employs high accuracy, low noise spindle bearings encased in lubricating and anti-rust oils. During shipping, vibrations may cause the spindle bearings to oscillate in small back and forth motions causing the bearings to push through the lubricating and anti-rust oils until there is metal-on-metal contact. The metal-on-metal contact creates micro spots of fretting corrosion which exacerbates acoustic noise and non-repeatable run-out (NRRO).

There is, therefore, a need for a disk drive which minimizes metal-on-metal contact of the spindle bearings due to vibrations during shipping.

SUMMARY OF THE INVENTION

The present invention may be regarded as a disk drive comprising a disk, a head actuated radially over the disk, and a spindle motor for rotating the disk. The spindle motor comprises a stator comprising at least one stator coil wrapped around a stator tooth. The spindle motor further comprises a hub rotated by the stator when current is applied to the stator coils, and a locking spring arm having a fixed base. The locking spring arm engages the hub when no current is applied to the stator coil, and the locking spring arm disengages from the hub when current applied to the stator coil generates a magnetic flux which pulls the locking spring arm away from the hub.

In one embodiment, the locking spring arm comprises a magnetic material for interacting with the magnetic flux. In another embodiment, the locking spring arm comprises a rubber material for engaging the hub. In one embodiment, the locking spring arm comprises a spring material for biasing the locking spring arm toward the hub. In yet another embodiment, the locking spring arm is non-elastic so that the locking spring arm remains disengaged from the hub when the current applied to the stator coil is turned off. In one embodiment, the locking spring arm comprises a substantially arcuate shape corresponding to an arcuate shape of the spindle motor, and in an alternative embodiment, the locking spring arm comprises a substantially circular shape corresponding to a circular shape of the spindle motor.

The present invention may also be regarded as a spindle motor comprising a stator having at least one stator coil wrapped around a stator tooth. The spindle motor further comprises a hub rotated by the stator when current is applied to the stator coil, and a locking spring arm having a fixed base. The locking spring arm engages the hub when no current is applied to the stator coil, and the locking spring arm disengages from the hub when current applied to the stator coil generates a magnetic flux which pulls the locking spring arm away from the hub.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded view of a disk drive according to an embodiment of the present invention comprising a disk, a head actuated radially over the disk, and a spindle motor for rotating the disk.

FIG. 2A is a cross-sectional view of the spindle motor in the disk drive of FIG. 1, including a locking spring arm for restraining movement of a hub during shipping and disengaged when current is applied to a stator coil of the spindle motor.

FIG. 2B shows further details of the locking spring arm, including a rubber material for engaging the hub.

FIG. 2C illustrates how the locking spring arm disengages from the hub when current is applied to the stator coil.

1 FIG. 3A shows an embodiment of the present invention wherein the base of the locking
2 spring arm is connected to a lamination of the stator.

3 FIG. 3B illustrates the flux from the stator coils pulling the locking spring arm away from
4 the hub when current is applied to the stator coils.

5 FIG. 4A shows a top view of a locking spring arm according to an embodiment of the
6 present invention comprising a substantially arcuate shape corresponding to an arcuate shape of
7 the spindle motor.

8 FIG. 4B shows a perspective view of the locking spring arm of FIG. 4A.

9 FIG. 5A shows a top view of a locking spring arm according to an embodiment of the
10 present invention comprising a substantially circular shape corresponding to a circular shape of
11 the spindle motor.

12 FIG. 5B shows a perspective view of the locking spring arm of FIG. 5A.

13 FIG. 6A shows a top view of a locking spring arm according to an embodiment of the
14 present invention comprising a spoke and wheel configuration.

15 FIG. 6B shows a perspective view of the locking spring arm of FIG. 6A.

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17 **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

18 FIG. 1 is an exploded view of a disk drive 2 according to an embodiment of the present
19 invention comprising a disk 4, a head 6 actuated radially over the disk 4, and a spindle motor 8 for
20 rotating the disk 4. As shown in the cross-sectional view of FIG. 2A, the spindle motor 8
21 comprises a stator 10 having at least one stator coil 14A wrapped around a stator tooth 12A. The
22 spindle motor 8 further comprises a hub 16 rotated by the stator 10 when current is applied to the
23 stator coils, and a locking spring arm 18 having a fixed base. The locking spring arm 18 engages
24 the hub 16 when no current is applied to the stator coil 14A, and the locking spring arm 18
25 disengages from the hub 16 when current applied to the stator coil 14A generates a magnetic flux
26 which pulls the locking spring arm 18 away from the hub 16.

27 In the embodiment of FIG. 2A, the spindle motor 8 comprises bearings 20A-20D encased

1 in lubricating and anti-rust oils. The bearings 20A-20D allow the hub 16 to rotate around a fixed
2 spindle shaft 22. The hub 16 comprises magnets 24A and 24B which interact with the flux
3 generated by the stator coils 14A and 14B to generate the torque which rotates the hub 16 around
4 the spindle shaft 22. The flux that rotates the hub 16 also interacts with the locking spring arm
5 18. During shipping, no current is applied to the stator coils and therefore the locking spring arm
6 18 engages the hub 16 to prevent it from rotating. This helps prevent the bearings 20A-20D from
7 pushing through the lubricating and anti-rust oils, thereby avoiding the metal-on-metal contact
8 that can exacerbate acoustic noise and non-repeatable run-out (NRRO). When the disk drive is
9 powered on and current is applied to the stator coils in order to spin up the disk 4, the flux
10 generated by the stator coils pulls the locking spring arm 18 away from the hub 16 allowing the
11 disk 4 to rotate freely.

12 The current applied to the stator coils is increased during the spin up process since it
13 requires more torque to accelerate the disk 4 than to maintain the disk 4 at the operating speed.
14 Accordingly, more flux is generated during the spin up process to help pull the locking spring arm
15 18 away from the hub 16. Once pulled away, less flux is needed to maintain the locking spring
16 arm 18 in the disengaged positioned.

17 FIG. 2B shows the locking spring arm 18 engaging the hub 16 during shipping to prevent
18 the hub 16 from rotating. In this embodiment, the locking spring arm 18 comprises a rubber
19 material 26 for engaging the hub 16. The surface of the rubber material 26 provides a high
20 friction coefficient so that it "sticks" to the surface of the hub 16. In this embodiment, the locking
21 spring arm comprises a magnetic material 28 which interacts with the flux generated by the stator
22 coil 12A. The magnetic material 28 is suspended by a spring material 30 comprised, for example,
23 of metal or plastic which is attached to the stator 10 and biases the rubber material 26 toward the
24 hub 16.

25 FIG. 2C illustrates operation of the locking spring arm 18 when the disk drive 2 is
26 powered on and current is applied to the stator coils in order to spin up the disk 4. The flux
27 generated by the stator coils pulls the locking spring arm 18 away from the hub 16 allowing it to

1 rotate freely. In one embodiment, when the current applied to the stator coil 12A is turned off the
2 elasticity of the spring material 30 repositions the locking spring arm 18 so that it engages the hub
3 16 as shown in FIG. 2B. In an alternative embodiment, the spring material 30 is non-elastic so
4 that the locking spring arm 18 remains disengaged from the hub 16 when the current applied to
5 the stator coil 12A is turned off.

6 In the embodiment of FIG. 2B, the spring material 30 comprises a ninety degree angle and
7 is connected to a bracket portion of the stator 10, however, the spring material 30 may comprise
8 any suitable shape and may be fixed to anything suitable, such as another part of the stator 10 or
9 even the spindle shaft 22. In the embodiment shown in FIG. 3A, the spring material 30 is
10 connected to one or more of the stator teeth 12A with FIG. 3B illustrating the disengaged
11 position of the locking spring arm 18.

12 The locking spring arm 18 may comprise any suitable shape. FIG. 4A shows a locking
13 spring arm according to an embodiment of the present invention comprising a substantially
14 arcuate shape corresponding to an arcuate shape of the spindle motor 8. FIG. 4B shows a
15 perspective view of the locking spring arm of FIG. 4A. FIG. 5A shows a top view of a locking
16 spring arm according to an embodiment of the present invention comprising a substantially
17 circular shape corresponding to a circular shape of the spindle motor 8. FIG. 5B shows a
18 perspective view of the locking spring arm of FIG. 5A. FIG. 6A shows a top view of a locking
19 spring arm according to an embodiment of the present invention comprising a spoke and wheel
20 configuration. FIG. 6B shows a perspective view of the locking spring arm of FIG. 6A.

21 In one embodiment, the shape of the locking spring arm 18 is selected so that it interacts
22 with the magnetic flux generated by a plurality of the stator coils. In this manner the locking
23 spring arm 18 is continuously affected by magnetic flux which pulls it away from the hub 16 even
24 though the stator coils may be activated according to a commutation sequence. For example, if
25 the spindle motor 8 of FIG. 1 is a three phase spindle motor, the shape of the locking spring arm
26 18 may be selected so that it is affected by at least three of the stator coils, two of which are
27 active at any given time. In an alternative embodiment, the shape of the locking spring arm 18 is

- 1 selected so that it is affected by a single stator coil. This embodiment will maintain the locking
- 2 spring arm 18 in the disengaged position as long as there is adequate coil current at a suitable
- 3 switching frequency for the commutation sequence relative to the mechanical response of the
- 4 locking spring arm 18.

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